The Economics of Obesity:

A Theoretical and Empirical Examination

[Preliminary and Incomplete]

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Abstract

This paper provides a theoretical and empirical examination of the forces that have been contributing to the long-run growth in weight over time. We stress the implications of the hypothesis that technological change has made home- and market-production more sedentary and has lowered the real price of food. Among other things, our analysis predicts that increases in income raise weight for the poor, but lower it for the rich, that gains in weight may often be accompanied by reductions in food consumption and gains in exercise, that earned income has a smaller effect on weight than unearned income, and predictions on how the price of food covaries with weight under our main hypothesis. We examine these predictions empirically using individual-level data on weight and occupation, along with measures of job strenuousness. We find fairly large effects of physical activity in market production on weight, a robust inverted U-shaped income profile on weight, and evidence for large year effects that are consistent with, but do not provide conclusive evidence in support of, technological change as the source of weight gains.

1 Introduction

Obesity seems to be a major health economic and public finance issue. Close to half the US population is currently estimated to be over-weight, and more Americans are obese than smoke, use illegal drugs, or suffer from ailments unrelated to obesity. A substantial risk factor for most of the high-prevalence, high-mortality diseases, including heart disease, cancer, and diabetes (Wolf and Colditz 1998), obesity affects major public transfer programs such as Medicare, Medicaid, and Social Security. Obesity also affects wages and the overall demand for and supply of health care, a sector that itself makes up about a sixth of the US economy.

Obesity is typically treated as a problem of public health or personal attractiveness. While it is those things, it is even more an economic phenomenon. More than many other physical conditions, obesity is avoidable by behavioral changes, which economists expect to be undertaken if the benefits exceed the costs. Naturally, people may rationally prefer to be under- or over-weight in medical sense, because weight results from personal choices along such dimensions as occupation, leisure-time activity or inactivity, residence, and, of course, food intake. Being either fat or thin may thus be as desirable from the individual's standpoint as adhering to the norms of weight set by doctors and the public health community.

Although the rise in obesity has gained recent attention, the long-run growth in weight does not appear to be a recent phenomenon. Figure 1, adapted from Costa and Steckel (1995), documents large secular gains in average height-adjusted weight by age for different birth cohorts over the last century. Indeed, the growth in weight is more pronounced in the early part of the century, although the extreme weights in the tails of the distribution may be a more recent phenomenon. Height-adjusted weight for people in their 40s, the age group with the highest labor force attachment, has increased by nearly 4 units over this period. To put this into perspective, an increase of this magnitude in the height-adjusted weight of a 6-foot-tall man would require a weight gain of approximately 30 pounds.

FIGURES 1 AND 2 INSERTED HERE

As Figure 2 illustrates, this secular growth in weight has been accompanied by only modest gains in calorie consumption. Indeed, the immediate post-war period seemed to entail substantial growth in weight with *declining* consumption of calories. The lack of correlation between calorie intake and weight suggests that the incentives determining the weight of a population must take into account not only food consumption but also the changes in physical activity over time, whether in home- or market production, that economic growth entails.

This paper builds on existing work (see Philipson and Posner (1998)) by stressing the hypothesis that technological change has simultaneously raised the cost of physical activity and lowered the cost of calories. It has raised the cost of physical activity by making household and market work more sedentary and has lowered the cost of calories through gains in agricultural efficiency. In an agricultural or industrial society, work is strenuous and food is expensive; in effect, the worker is *paid* to exercise and must forego a larger share of his income to replace the calories spent. In addition, with the low levels of welfare characteristic of these societies, the cost of not exercising could even include starvation. Technological change has freed up resources previously used for food production and has enabled a reallocation of time to the production of other goods and, in particular, more services. In a post-industrial and redistributive society, such as the United States, most work entails little exercise and not working may not cause a reduction in weight, because food stamps and other welfare benefits are available to people who do not work. As a result, people must *pay* for undertaking, rather than be paid to undertake, physical activity and have to devote smaller shares of their income to replace the calories spent. Payment is mostly in terms of forgone leisure, because leisure-based exercise, such as jogging or gym activities, must be substituted for exercise on the job as production becomes more technologically advanced. Such technological improvements may raise income, but may also raise weight as well by lowering the amount of physical activity.

The paper may be outlined as follows. Section 2 considers the determinants of steady state weight in a dynamic model of weight-management. We stress the complementarity in physical activity and food intake that seems important for understanding the lack of correlation between food consumption and weight. As an economy goes through sedentary technological change in home or market production, people may eat less but weigh more. As such growth takes place, we stress that income growth has different effects depending on how that income is generated. We argue that *unearned* income may initially raise weight, but then eventually may lower weight. However, *earned* income may have different effects on weight, when earnings affect one's physical activity. This impact of technological change on physical activity may be important in understanding why empirical inter-country comparisons, in which technologies differ greatly, display a positive relationship between income and weight while intra-country comparisons, in which technologies differ less, reveal an inverted U-shaped relationship. In addition, we predict that since sedentary technological expands food supply or lowers food demand, weight gains should be accompanied by reductions in the relative price of food.

Section 3 examines these predictions empirically using individual-level data from the National Health Interview Survey (NHIS), the National Health and Nutrition Examination Survey (NHANES), and the National Longitudinal Survey of Youth (NLSY). We are able to merge these data in a unique way with measures of job strenuousness. This allows us to assess whether workers in sedentary jobs weigh more than other workers, controlling for other factors. We find that a worker who spends her career in a strenuous job may end up with as much as 3.3 units of BMI less than one in a sedentary job. To put the size of this effect in perspective, we see from Figure 1 that this cross-sectional difference is about as large as the total gain in weight that has taken place over the last century. We also find support for the surprising inverted U-shaped relationship between income and weight, but find generally that job strenuousness effects are larger in magnitude than other measures often thought to be important for human capital investments, such as income and education. Finally, we attempt to evaluate the evidence for technological change by considering the importance of time-trends as opposed to composition effects in explaining the recent observed growth in income. We find that, holding the composition of the population fixed, BMI rose by about 0.1 units per year from 1976 to 1994, and that the proportion of weight gains that can be explained by composition effects is very small. In addition, this secular growth in weight has been accompanied by significant declines in the relative price of food, as the theory predicts. Along several dimensions, these increases seem consistent with our prediction that technological change, whether through gains agricultural efficiency or through more sedentary home- or market production, raises weight.

2 Theoretical Analysis

2.1 The Dynamics of Weight Management

Suppose that an individual's current period utility depends on food consumption, other consumption, and her current weight. We can write this as $U(F,C,W)$, where U rises in food consumption and other consumption, but is non-monotonic in weight. In particular, suppose that for a given level of food and other consumption, individual i has an "ideal weight," W_i, which she does not like to depart from in the following sense: all else equal, she prefers to gain weight when her weight is below W_i but she prefers to lose it when her weight is above W_i. In addition, suppose that food consumption and material consumption C are not substitutes, in the sense that $U_{FC} \geq 0$. This rules out any perverse incentives for richer people at higher levels of material consumption to eat less than poorer people.

We formulate the dynamic problem by taking the individual's weight, W, to be the state variable. Her weight next period, W', is influenced by her current weight, her chosen food consumption F, and the strenuousness of her home- or market production activities, S: $W' = W + g(F,S)$, where $g(F,S)$ is continuous and concave, rises in food consumption, but falls with job-related exercise.[1] The associated value function for an individual with income Y is given by:

$$\begin{aligned} &v(W) = \max\{U(F,C,W) + \beta v(W')\} \\ &s.t.\ pF + C \leq Y \\ &W' = W + g(F,S) \end{aligned} \tag{1}$$

Provided that the utility function U is continuous, strictly concave, differentiable, and bounded, and that the transition function g is continuous and concave, we can differentiate the value function, which is continuous and strictly concave. This leads to the first order and envelope conditions:

$$\begin{aligned} &U_F(F,Y-pF,W) + \beta v'(g(W,F,S)) * g_F = pU_C(F,Y-pF,W) \\ &v'(W) = U_W(F,Y-pF,W) + \beta v'(W') \end{aligned} \tag{2}$$

The first order condition implies that the marginal utility of consumption must be equal to the overall marginal utility of food, which equals the marginal utility of eating *plus* the marginal value of the weight change induced by eating. The envelope condition implies that the marginal value of additional weight is equal to the marginal utility of weight in the current period plus the discounted future marginal utility of weight.

[1] Stability is ensured as long as current weight has a weakly concave effect on future weight. This rules out explosive growth in weight.

A steady state weight level is one for which the future weight induced by optimal food consumption is equal to current weight:

$$0 = g(F(W,S),S) \tag{3}$$

Under a steady state the envelope condition implies

$$v'(W) = \frac{U_W}{1-\beta} \tag{4}$$

Substituting equation 4 into the first order condition in 2 results in the steady-state first order condition:

$$U_F(F, Y - pF, W) + \frac{\beta}{1-\beta} U_W g_F = pU_C \tag{5}$$

The two conditions in (3) and (5) determine W and F in the steady state. We now consider the incentives affecting the steady state level of weight of an individual.

The Impact of Calorie Expenditure Levels

The steady state level of food consumption and weight are affected in important ways by the level of calorie expenditure, S. An important implication is that food consumption and calorie spending are complementary in the sense that S raises F, but not to the extent of offsetting fully the effects of exercise on weight. To understand the effect of strenuousness on food consumption, we implicitly differentiate the condition in 5 to obtain:

$$\frac{\partial F}{\partial S} = \frac{1}{D} \frac{\beta U_W g_{FS}}{1-\beta}, \tag{6}$$

where D is positive as long as the second order conditions hold. If increases in food consumption partially offset the weight loss induced by more exercise, it will be the case that $g_{FS} \geq 0$.[2] This then implies that food consumption rises with strenuousness. Conversely, reductions in strenuousness lower food consumption. As an economy becomes more sedentary, weight gains may be accompanied by modest gains or even falling food consumption, as appears to have been the case in the aggregate time-series of the US.

When strenuousness falls, however, reductions in food consumption cannot reverse the weight gain induced. When S rises, the first-order effect is to lower future weight W'. This first-order effect will not be offset by adjustments in food intake, because the initial fall in future weight (W') is what induces the increased food consumption in the first place. Increased strenuousness shifts up the policy function for food $F(W,S)$, but shifts down the transition function for weight

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[2] This result holds even outside a steady-state, as long as $g_{FS} \geq 0$.

$W'(W,S)$. In the special case of a steady-state, this implies that an increase in strenuousness must raise steady-state food consumption, even though it lowers steady-state weight.

The Effect of Income on Weight

Increases in income will initially raise weight, but at high levels of income, further increases could actually lower weight. In other words, income has an inverted U-shaped relationship with weight. Comparative statics reveal that:

$$\frac{\partial F}{\partial Y} = \frac{U_{FC} + \frac{\beta g_F}{1-\beta} U_{WC} - pU_{CC}}{D}, \tag{7}$$

where D is positive if the second-order conditions hold, because it is of opposite sign of the negative second derivative of the objective function. Suppose that food and consumption are complementary, and that closeness to ideal weight and consumption are complementary. In other words, richer people place a higher value on food consumption and on attaining ideal weight. Under these conditions, income always raises weight for an individual under her ideal weight, but may *lower* weight for an individual above her ideal weight. Observe first that $U_{FC} > 0$. The key to this result is the behavior of U_{WC}. For an underweight individual, weight gain is a good and is required for the individual to move closer to ideal weight. Therefore, weight gain and consumption are complementary, or $U_{WC} > 0$. An underweight individual, therefore, will always gain weight when income rises. However, for an overweight individual, weight *loss* allows the individual to move closer to ideal weight, and weight loss is complementary with consumption, or $U_{WC} < 0$. As a result, income growth may lower the weight of overweight individuals. Income growth initially raises weight, but once individuals become overweight, further growth will lower their weight.

These effects are reinforced by the relationship between income and discounting. Since weight is the durable, capital good in this model, people who are more forward-looking will place relatively greater value on being closer to their ideal weight. Richer people will tend to be more forward-looking for a variety of reasons. First, if we interpret β as the probability of surviving to the next period, richer people will have a higher value of β because they live longer. Second, richer people may have incentives to discount the future less (Becker and Mulligan 1997). Therefore, high incomes coincide with more forward-looking behavior, which in turn pushes an individual closer to ideal weight. For underweight individuals, this will generate a positive relationship between income and weight, but a negative relationship for overweight individuals. This relationship is evident when we differentiate the steady state equation 5 with respect to the discount factor:

$$\frac{\partial F}{\partial \beta} = \frac{1}{D} \frac{U_W g_F}{(1-\beta)^2}, \tag{8}$$

where D is positive by the second-order condition. For underweight individuals, $U_W > 0$, and thus $\frac{\partial F}{\partial \beta} > 0$. Conversely, for overweight individuals, $U_W < 0$ and $\frac{\partial F}{\partial \beta} < 0$.

Sedentary Technological Change and Differences in Income Effects

We have assumed thus far that increases in income through technological change occur independently of any changes in physical activity. When technological change affects the physical activity required to participate in market or non-market production, we denote by S(Y) the calories spent under the technology that generates per-capita income I. We say that income enhancing technological change is *sedentary* if this function is decreasing and *non-sedentary* if it is non-decreasing.

If $W(Y, S(Y))$ denotes the steady-state weight under income Y and calorie expenditure $S(Y)$, the total effect of income on weight is made up of the direct effect of income (the pure income effect) and the indirect effect of income that operates through changes in calorie expenditure. That is,

$$\frac{dW}{dY} = W_Y + W_S S_Y \tag{9}$$

If technological change does not affect physical activity, that is, if $S_Y=0$, the pure income effect drives changes in weight. We have seen that this pure income effect may be positive for low incomes and negative for higher incomes. However, if technological change affects physical activity by making it more sedentary, the overall correlation between weight and income can change. Weight may rise with income since income induces a more sedentary life-style.

This distinction is useful in understanding the effect of income differences within countries, between countries, and over time. First, within a country, income has different effects depending on whether it was earned in the labor market or not. Unearned income may come, for example, from asset markets or from the income of a spouse. If work is sedentary, an increase in earned income will have a larger effect on weight than an increase in unearned income, because earned income includes the effect of holding a sedentary job. If $S_Y < (>) 0$, $\frac{dW}{dY}$ is higher (lower) for earned income. Put differently, when work is sedentary, getting rich through the labor market will raise your weight more than getting rich through the asset market.

Second, within-country income effects may differ from between-country income effects. Empirically, within developed countries, there tends to be a non-monotonic income effect on weight, as we will show later on. However, across countries, income tends to be correlated with higher weight; less developed countries tend to be lighter than more developed countries. A natural way to interpret this is to argue that differences in technology are much larger between countries than within them. This would mean that cross-country income differences reflect much greater differences in technology levels than within-country income differences. In other words, there may be a greater difference between the strenuousness of work in poorer and richer countries, than between the strenuousness of work for poorer and richer people within a rich country. As a result, S_Y would be much more negative between countries than within countries. This helps us understand why $\frac{dW}{dY}$ is larger between countries than within countries.

Third, the time-series behavior of obesity depends on whether the pure income effect or the effect of sedentary technological change dominates. Historically, income and weight have grown together, indicating either that the pure income effect has remained positive, or that the effect of sedentary technological change has dominated the pure income effect. While this has been true in the past, it need not remain true forever. The future course of obesity will depend on which effect dominates the time-series behavior of weight.

2.2 The Market Implications of Technological Change

The previous analysis stressed the complementarity between calorie consumption and calorie expenditure on physical activity. This section considers the market implications of this complementarity when agricultural advances affects the food supply and when home and market-production become more sedentary.

Denote the supply of food by $Z(p,T)$, where T is a real-valued parameter representing technological change in food production; growth in T shifts supply outward. The equilibrium price for a given level of physical activity and technology is determined implicitly by:

$$F(p(T,S),S) = Z(p(T,S),T) \tag{10}$$

Now suppose that technological change in food production over time is represented by the increasing function $T(t)$, and suppose that sedentary technological change in home and market production is represented by the decreasing function $S(t)$. Implicitly differentiating yields the effect of both types of technological change on the price of food:

$$\frac{dp}{dt} = p_T T'(t) + p_S S'(t) = \frac{Z_T T'(t) - F_S S'(t)}{F_p - Z_p} < 0 \tag{11}$$

The denominator of this expression is always negative, because a rise in price always reduces excess demand. The numerator is always positive, because technological change in food production raises supply, $Z_T > 0$, and because food consumption and physical activity is complementary, $F_S > 0$. The total effect on price over time is therefore negative. Sedentary technological change reduces the demand for food, while technological change in agriculture raises the supply of food. Both these forces tend to lower food prices.

The quantity of food demanded in equilibrium changes according to:

$$\frac{dF}{dt} = F_p \frac{dp}{dt} + F_S \frac{dS}{dt} \tag{12}$$

Even though food prices always fall, the effect on food consumption is ambiguous, because the reduction in physical activity lowers the demand for food. Even though the effect on food consumption is ambiguous, technological change always raises weight. Technological change raises the supply of food; this clearly raises weight. However, even though technological change may lower the demand for food, it will still raise weight, because reductions in strenuousness always raise weight. Any accompanying reduction in food consumption can only partially offset the growth in weight.

The price effects of technological change allow us to distinguish our model from other important explanations for the growth in weight, such as growth in the demand for food. Suppose we interpret S as a positive demand shifter for food. Growth in the demand for food can thus be modeled as $S'(t) > 0$. If the demand for food grew, weight would grow also, but there would be significant upward pressure on the price of food. This could result in higher relative food prices, if it offset the effect of technological change in food production. Indeed, in the absence of technological change in food production, growth in the demand for food implies increasing relative prices of food. This is in stark contrast to our model of technological change.

3 Empirical Analysis

In the subsequent empirical analysis, we develop methods for testing three key implications of the model: (1) Unearned income initially raises BMI, but subsequently lowers it; (2) Reduction in occupational strenuousness significantly raises BMI; (3) Technological change causes long-run expansion in weight, but long-run decline in the price of food.

3.1 Understanding Nationwide Trends in Weight

Data from the National Health Interview Surveys (NHIS) and the National Health and Nutrition Examination Survey (NHANES) will be used to test the predictions of the model. While we will find evidence consistent with all three of our predictions, in this section we focus particularly on understanding the relationship between expansion in weight and changes in the price of food. Nationally representative data sets such as the NHIS are particularly well suited to this type of analysis.

3.1.1 The Data Sets: NHIS and NHANES

The NHIS contains individual-level data on height, weight, income, education, demographic variables, and occupation. It is a repeated cross-section done every year for several decades. Our analysis uses every survey year from 1976 through 1994. Prior to 1976, the NHIS did not ask respondents about their weight. After 1994, it switched to a much coarser occupational classification system; initial analysis has revealed that this classification system is too coarse for our purposes.

Use of the NHIS requires us to solve two measurement issues. First, before 1983, the NHIS uses an occupational classification scheme based on the 1970 Census, but from 1983 onwards, its scheme is based on the 1980 Census. The differences between these two schemes are substantial. Second, the data on height and weight are self-reported, rather than measured. Self-reported data on weight tends to be systematically misreported (Cawley 2000).

To address the first problem, we rate 1970 and 1980 U.S. Census occupations using *consistent* measures of strenuousness with the help of two additional data sets. The *Dictionary of*

Occupational Titles, Fourth Edition, by the Department of Labor's Bureau of Labor Statistics, contains various ratings of the strenuousness of each 3-digit occupational code from the 1970 Census. In the past, this data set has been used primarily to study Workers' Compensation issues rather than the occupational effects stressed here.[3] We will use these publicly available data to rate the physical demands of each 3-digit occupational category in the 1970 U.S. Census. We focus on two ratings in particular: a rating of strength, and a rating of other physical demands, including climbing, reaching, stooping, and kneeling. It is important to separate strength requirements from other physical requirements, because stronger workers with greater muscle mass may weigh more than other workers, even though they are not more "over-weight" in any medically relevant sense. The 3-digit 1980 U.S. Census occupations can be rated according to the same set of measures, using the work of England and Kilbourne (1988). England and Kilbourne use a sample of individuals from the 1970 U.S. Census who were assigned occupational codes both from the 1970 U.S. Census and from the 1980 U.S. Census. They then assign strenuousness scores to each such individual, based on her 1970 U.S. Census occupational code. These strenuousness scores are averaged within each 1980 U.S. Census code to obtain an average strenuousness score for each 1980 code. This method allows us to measure job-related exercise under both systems of occupational classification. Even though these ratings span two types of occupational classification, they are both based on a single, consistent measure of job-related exercise, taken from the *Dictionary of Occupational Titles*.[4] It is important to stress here that the measures of strenuousness are ordinal, not cardinal, in the sense that we only observe the rank of an occupation in the S-distribution. We do not observe an absolute measure of calories spent per hour worked. Since the data are ordinal, cross-sectional comparisons may be more meaningful than panel estimates because the *absolute change* in the level of S is unobserved.

To address the second problem, we use data from Wave III of the NHANES, which was collected from 1988 to 1994. The NHANES is an individual-level data set containing both self-reported weight and height, *and* measured weight and height, for each individual in the sample.[5] Following the method of Cawley (2000), we use the NHANES to correct for reporting error in the NHIS, by estimating the relationship between self-reported weight and actual weight. We regress self-reported weight and its square on actual weight. This regression is run separately for white males, white females, non-white males, and non-white females, where all individuals are over age 18. The R-Squared for all these regressions is over 90 percent, indicating that the quadratic function fits the data quite well. The results are presented in Figure 3, which plots the predicted reporting bias against self-reported weight for the four sex-race cells used. Nearly all women tend to under-report their weight; the under-reporting is somewhat greater for non-white women than for white women. The reporting patterns of men, on the other hand, differ more by

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[3] These data are published most conveniently as a supplement to the April 1971 CPS, which reports 1970 Census occupation and various occupational characteristics for each CPS individual.

[4] The only relevant difference is that the scores based on the original 1970 Census codes are integer-valued, while the scores translated into the 1980 Census codes can take decimal values, because they are averages of integers.

[5] Unfortunately, the NHANES cannot be used to test the predictions of our model directly, because it, like the 1995 and later NHIS, uses a very coarse system of occupational classification.

weight. Lighter men, who report weight under 100 Kg, tend to say they are heavier than they really are, while heavier men tend to understate their weight. Using the estimated relationship from the NHANES data, we predict actual weight in the NHIS from the self-reported weight data.[6] All our analysis is performed using this constructed series. Correcting for reporting error improves the fit of our regressions slightly, but it does not change the qualitative results.[7]

The major trends in weight and occupation, for adult men and women in the labor force, are summarized in Table 1. From 1976 until 1994, there has been substantial growth in BMI, amounting to about five percent of its 1976 level.

TABLE 1 INSERTED HERE

More strikingly, the rate of obesity has roughly doubled for both men and women in the labor force. There has been a shift out of more strenuous jobs to less strenuous ones, and this shift has been even more pronounced for female workers than for male workers.

3.1.2 The Determination of Weight

After calculating each individual's BMI (equal to weight in kilograms, divided by the square of height in meters), we estimate the following specification[8]:

$$W_{it} = \beta_0 + \beta_1 Year_t + \beta_2 Muscle_{it} + \beta_3 S_{it} + \beta_4 Y_{it} + \beta_5 (Ed_{it}) + \beta_6 (Age_{it}) + \beta_7 (Age_{it})^2 + \varepsilon_{it} \quad (13)$$

$Year_t$ represents a vector of year dummies. $Muscle$ reflects the strength requirement of a worker's job, taken from the *Dictionary of Occupational Titles*. The variables W and S are the same as in the theoretical section: they are BMI and job strenuousness (other than strength). Job strenuousness is separated from strength, because they are predicted to have different effects. Stronger workers will have greater muscle mass and thus greater BMI. We predict that $\beta_2 > 0$ and $\beta_3 < 0$. Y represents income, just as in the theory section, but in this regression, Y will be included as a set of dummies indicating the quartile of the income distribution to which a worker belongs. There are two reasons for this. First, this specification allows for the inverted U-shaped relationship we predict. Second, the NHIS reports a person's income category, not his actual income. It is not possible to include a continuous measure of income. The inverted U-shaped relationship is true *conditional* on a level of job-related exercise, but it will not be

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[6] This general strategy for correcting reporting error is presented in Lee and Sepanski (1995), and Bound et al (1999). Cawley (2000) applies this strategy to predicting young women's weight.

[7] The improved fit seems expected but the unchanged coefficient estimates seem unexpected, especially for males. Classic measurement error (mean zero and independent of covariates) should affect only the standard errors. However, when the light over-report their weight and the heavy under-report it, these *systematic* errors in the dependent variable might also bias the coefficients toward zero.

[8] Although obesity concerns the upper tail of the weight distribution, the specification is in terms of the mean weight. The same type of specification was estimated using quantile regressions for the 0.25, 0.5, and 0.75 quantiles, but this did not change the qualitative findings.

unconditionally true. Unconditionally, at higher incomes, job-related exercise is lower, and weight may be rising unconditionally. In addition, it will not be true if we condition on food intake: income initially raises weight precisely because it raises food intake. Finally, note that for biological reasons, we also allow for weight to have an inverted U-shape in age: people gain weight as they approach middle age, but they begin to lose weight as they enter old age: β_6 should be positive, while β_7 should be negative.[9] In addition to the listed variables, we also include race and marital status.

The results of estimating equation 13 for male workers are presented in the first few columns of Table 2. The coefficient on S is negative and highly significant. Since S is measured on a scale of zero to three, this implies a difference of nearly 0.9 units of BMI between the most sedentary and least sedentary male workers.

INSERT TABLE 2 HERE

This effect of job strenuousness is large relative to the effects of other economic factors that are often stressed as key determinants of weight, such as income and education. To put this number in context, observe that one grade level lowers BMI by 0.1 units. A one-unit increase in strength requirements, on the other hand, raises BMI by 0.3. As predicted, income has an inverted U-shaped effect on the BMI of male workers. BMI rises by about 0.2 units between the first and second income quartiles and remains flat through the second and third quartiles. It then drops by 0.1 units for the fourth quartile. Age also has an inverted U-shaped effect on weight. We also find that black men, on average, have slightly higher BMI than white men, by about 0.2 units. Married men weigh much more than unmarried men; their BMI is higher by about 0.7 units.

The results for female workers, also shown in Table 2, also display the inverted U-shaped effect in age, and the negative effect of education. However, they also reveal two important differences. First, the coefficient on S is about one-half the size for women than for men, although it is still significant. Below, we explain that this may be an artifact of the way strenuousness scores were translated into the 1980 Census occupational classification scheme. Second, income seems to exert a consistently negative effect on the BMI of women, rather than an inverted U-shaped impact. In our analysis of the NLSY data below, we will show that this is an artifact of using total family income, rather than just unearned income. It turns out that unearned income does exert an inverted U-shaped effect on the BMI of women.

We ran two important tests to ensure the stability of this model over time. First, we ran these regressions year by year, and found that there was little variation in the coefficients. The

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[9] We should mention here the possible impact of omitted variables on this regression. The most relevant are those relating to recreational exercise, transportation choices, and housing location choices. Controlling for income, however, all workers face the same incentives for choice among these variables, except that more sedentary workers have a greater incentive to make choices that increase their exercise level. As a result, these omitted variables may bias the results against our predicted effect of job-related exercise: β_2 will be biased toward zero and will actually understate the total effect of job strenuousness on obesity.

coefficient on S for females presents the single exception to this finding. This coefficient is not very stable over time. It tends to be larger in absolute value before 1983, and considerably smaller after 1983. This probably owes itself to the change in the occupational classification scheme in 1983. To see how this works, we should explain how strenuousness ratings are constructed for the 1980 Census occupations. Fundamentally, they are constructed from a 1970 sample of workers whose occupations were coded according to both classification schemes. The DOT strenuousness scores for the 1970 occupations were then averaged within each 1980 occupation, in order to yield a strenuousness score for each 1980 occupation. This procedure may break down if there is a set of heterogeneous occupations within each 1980 occupation code, where some are strenuous, and some are not so strenuous. If workers are uniformly distributed between these two sets of occupations, the average strenuousness score is still valid. However, suppose that women are located primarily in the, say, less strenuous half of the occupational distribution. If so, then the average strenuousness scores would be invalid for women. The 1980 strenuousness scores would then be measured with error, and the coefficient on S would be biased toward zero for women. This explanation is consistent with the NLSY results we present below. The NLSY consistently codes individuals according to the 1970 Census classification. Using this single scheme, the effect of strenuousness for women becomes as large as it is for men in the NHIS regressions.

Second, we interacted S with the year dummies, to see if the effect of strenuousness varied over time. These interaction terms were not significant at the one percent level for men. They *were* significant for women, but only because the strenuousness coefficients were considerably higher before 1983; they tended to be in the neighborhood of -0.2. The strenuousness coefficient of -0.10 should thus be regarded as a lower bound, since it is heavily influenced by the post-1983 strenuousness scores.

3.1.3 Changes in Weight and the Price of Food

The persistent growth of BMI across years, from 1976 to 1994, is indeed striking. After controlling for strenuousness, and all the covariates listed above, we find a secular increase in BMI, of about 1.3 units, from 1976 to 1994. This represents about 85% of the total growth in BMI over this time period. In two important respects, it is consistent with our prediction of falling occupational strenuousness and an expanding supply of food. These forces should generate a secular increase in BMI, accompanied by falling relative food prices. The NHIS regressions provide evidence of this secular growth in weight, and in this section, we show that this secular growth did coincide with falling relative food prices.

Our theoretical analysis stressed the market implications of an expansion of the food supply through technological change and a fall in physical activity. As both these changes are argued to take place over time, and one shifts the supply curve and the other the demand curve, differences in quantity and price across regional markets cannot identify demand and supply schedules. However, our analysis implied that price and weight should covary negatively whenever food consumption was rising. To test this implication, we construct time series for relative food prices in each of the four regions of the US--Northeast, North-Central, South, and West. The relative food price data are based on Bureau of Labor Statistics price indices for the regional price of food, and the regional price of all goods. We simply deflate the regional price of food by the regional price of all other goods, to obtain the relative price of food. Specifically, we use the price of food *at home* as our measure of food costs, because we wish to separate the costs of labor and capital that might be associated with food in restaurants.[10] Figure 5 depicts the resulting time-series for relative price changes. It is immediately apparent that the relative price of food declined precipitously from 1978 to 1985, the start of our period of analysis, and remained roughly at that level. During this initial period, the relative price of food declined by almost twenty percentage points. This sharp decline in the relative price of food, accompanied by sustained increases in BMI, is consistent with our argument.

To analyze the relationship between price and BMI more carefully, we aim to correlate the residual variation in BMI with the price variation that results from technological change. In other words, we want the variation in BMI and in price that results from technological change, rather than from demographic factors. To isolate this residual variation in BMI, we regress BMI on demographic factors: S, $Muscle$, marital status, dummies for income quartile, race, age, age squared, highest grade attained, and a set of region dummies. In other words, we run the fully specified regression in Table 2, but without the year-specific fixed effects. We exclude the year dummies, because we wish to retain the BMI variation that occurs across time, but not across demographic groups. To isolate the corresponding price variation that results from technology, we regress price on the same set of explanatory variables. The resulting price and BMI residuals are averaged within region and year, to create a data set with 76 observations—four observations per year, for 19 years. We compute an average for each region and year, because there is only one price observation per region-year. Therefore, this procedure allows us to calculate valid standard errors. The results of correlating the two data series are reported in Table 3.

The table reports the correlation estimated from regressions of the BMI residual on the price residual. There is a clear negative correlation between weight changes and price changes. This correlation is robust to a wide variety of different assumptions about the appropriate error structure. We allow for heteroskedasticity, correlation across regions, autoregression of order 1, and a general, unstructured form of autocorrelation.[11] The estimated correlation is always negative and significant in every case, except for the correlation between male BMI and price, when we allow for cross-regional correlation and autoregression of order 1. Apart from this case, which involves extremely highly correlated error terms, the correlation is always statistically significant, often at the 1% level. These results are consistent with our argument that growth over time in BMI is accompanied by declines in the relative price of food.

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[10] The BLS did not begin to separate the price of food at home until 1978. To obtain values for 1976 and 1977, we assume that the price of food at home grew over this period at the same rate as the price of all food. This allows us to estimate price indices for food at home from price indices for all food, which are available for 1976 and 1977.

[11] To allow for a general form of autocorrelation, we use the method of Generalized Estimating Equations (GEE), with the assumption of Gaussian errors and heteroskedasticity across regions. For a discussion of GEE, see Liang and Zeger (1986).

3.2 Panel Data Analysis

The NHIS and NHANES represent valuable sources of nationally representative data on weight, but they have two shortcomings. First, the determination of weight is largely a dynamic, rather than static, outcome. While a person's current job undoubtedly has an impact on her weight, her entire work history should be considered in analyzing her weight. We were not able to analyze the impact of work history using the NHIS and NHANES, but we can do so using the panel structure of the National Longitudinal Survey of Youth (NLSY). Second, the NHIS and NHANES do not permit precise analysis of the relationship between income and weight, because their income measures are rather crude. To supplement the previous analysis, we use the National Longitudinal Survey of Youth (NLSY), to understand the long-run effects of occupation on weight, and to separate the effects of earned and unearned income on weight.

The NLSY data analysis will have two important goals: (1) Estimate the effect of staying in a sedentary occupation over a longer period of time; (2) Separate the effects of unearned income from those of earned income. We find that staying in a sedentary occupation for 14 years has four times the effect on weight as staying in it for one year. As a result, we predict that the younger NLSY cohort will have about 0.25 to 0.5 units more BMI than the population average. This is quite significant, even in the broader historical context of BMI growth. In addition, we find that unearned income initially raises weight, but then lowers it. Moreover, the effect of unearned income is larger in magnitude than the effect of earned income. Both these results are consistent with the predictions of the model.

3.2.1 The Data Set: NLSY

The NLSY started in 1978 with a cohort of 12,686 people aged 14 to 22. It followed this cohort over time, with the most recent survey being in 1998. The NLSY asked respondents about their weight in 1982, 1985, 1986, 1988, 1989, 1990, 1992, 1993, 1994, and 1996. It also asked respondents about their height in 1982 and 1985. Since all respondents were over age 21 in 1985, we take the 1985 height to be the respondent's height for the remaining survey years. In addition to questions about height and weight, the NLSY asked respondents about their race, sex, marital status, age, and the individual's occupation in terms of the 1970 Census classification. This occupation coding allows us to merge the strenuousness measures from the Dictionary of Occupational Titles. It is advantageous that the NLSY maintains a consistent occupational coding scheme throughout the panel; this alleviates the need to translate strenuousness scores from the 1970 Census occupational classification scheme to the 1980 scheme. The NLSY asks detailed income questions. We use data on wages earned, the primary source of earned income, as well as data for married people on wages earned by a spouse; this latter variable represents the primary source of unearned income for young people. These variables allow us to look separately at the effects of earned and unearned income.

The NLSY data are summarized in Table 4, for working men and women over the age of 18.

INSERT TABLE 4 HERE

The table presents the change over time in the NLSY cohort's characteristics, from 1982 (the first year during which every member of the cohort is over 18) to the end of the sample frame in 1998. As the cohort ages, its BMI rises by about 3 or 4 units, while its prevalence of obesity increases at least fourfold. From these data alone, however, we cannot separate the effect of aging from the effect of population-wide changes in the determination of weight. Aging also seems to affect the distribution of occupations. People seem to be moving into the second level of strenuousness and strength, out of the most strenuous occupations and the least strenuous occupations. It is also interesting to compare the distributions in table 4 to the corresponding ones in table 1: the younger NLSY cohort engages in substantially less strenuous occupations than the overall population. Even by 1998, when the NLSY cohort reaches the average age of the NHIS population, its occupations are substantially less strenuous. This provides important evidence of an intergenerational shift out of more strenuous occupations into less strenuous ones. In fact we will argue that these cohort shifts result in significant BMI growth, and that occupational shifts seem to explain long-run growth in BMI.

3.2.2 The Long-Run Impact of Occupation

A worker in a sedentary job may not gain weight immediately, but may do so over a number of years. Therefore, we would like to know how much a worker's weight changes when faced with a sedentary occupation over a number of years, and how this compares to the change induced over a shorter period of time[12]. Table 5 sheds some important light on these questions, for working women in the NLSY.

INSERT TABLE 5 HERE

The first column of the table shows the results of a regression, pooled across years from 1981 through 1996, of BMI on various characteristics for working women over the age of 18. Since individuals enter this regression more than once, standard errors are clustered by individual. This regression is identical to the fully specified NHIS regressions. [13] The coefficients are also quite similar, in sign and magnitude, with two exceptions. The effects of job strenuousness and strength requirements are substantially larger in the NLSY than in the NHIS. This is consistent with our argument that strenuousness for 1980 Census occupations is mismeasured for women. The NLSY consistently uses the 1970 Census occupations and does not suffer from this problem of mismeasurement. The difference in magnitudes could also be generated by stronger labor force attachment among younger working women. Job strenuousness is a better measure of overall exercise for those who are highly attached to the labor force. In either case, we argue that exercise is better measured for the younger women in the NLSY than for the average woman in the NHIS. The second exception bears on the effect of income: Within the lower deciles, earned

[12] Throughout this analysis, the problem of weight reporting is handled exactly as it was with the NHIS. We estimate the relationship between measured weight and reported weight for women in the NHANES III data set, for individuals between the ages of 18 and 40, by race. This estimated relationship is then used to impute measured weight for the women in the NLSY data set.

[13] Values for 1998 are not available, because we measure earnings for the *current* calendar year, rather than the previous calendar year. For example, to construct 1986 earnings, we take the value from the 1987 survey, in which the respondent is asked to report his 1986 earnings. Moreover, since respondents are never explicitly asked about 1994 or 1996 earnings (only 1993, 1995, and 1997 earnings), we exponentially interpolate to obtain values for these two years. Therefore, values for these two years are defined only if the person reports nonzero earnings in both adjacent years.

income seems to have no effect on weight, although high earned income does correspond to lower weight. We do not see the significantly negative effect in the lower deciles that we saw in the NHIS. Later, we will examine the effect of income more carefully, by breaking apart the effects of earned and unearned income for married women.

Since strenuousness is measured on a scale of one to three, a woman who spends one year in the least strenuous job has 0.9 units of BMI more than one who spends a year in the most strenuous job. Our weight data, however, span 14 years, from 1982 to 1996. Therefore, we can estimate the effect on weight of spending 14 years in a particular type of occupation.[14] For each woman in 1996, we construct the average level of strenuousness and strength required across every year for which she reports an occupation. The average is not weighted, although some experimentation with different weighting schemes suggested that the weights are not crucial. We then use 1996 data for working women (i.e., working in 1996) to run a single year regression of current BMI on average strenuousness measures, along with current demographic and income characteristics. The results are given in the second column of the table. The long-run effects of occupation seem to be almost four times as large as the one-year effects.

Since many people spend decades of their lives working, the long-run effect is the economically significant one. To illustrate, let us calculate the long-run weight difference between the NLSY cohort and the overall population taken from the NHIS. This comparison is important, because the NLSY represents the entering cohort of young workers and reveals the direction of future trends in weight. Using these long-run estimates, along with the distribution of strenuousness, the young NLSY women will have more than 0.3 units of additional BMI than the average woman, adjusting for age, marital status, education, and race: they will lose 0.2 units of muscle, but will gain 0.5 units as a result of reduced strenuousness. If we apply these coefficients to males, the effects are even larger, because occupational change has been more dramatic for males. In particular, the young NLSY men would possess almost 0.4 more units of BMI than the average man in the NHIS: 1 additional unit would come from reduced strenuousness, while loss of muscle would lower BMI by 0.6 units.

These results also demonstrate that the endogeneity of occupational choice is not a serious issue. Suppose that occupation were entirely endogenous: at youth, heavier people sorted themselves into sedentary occupations, but occupation had no further effect on weight. If this were true, the contemporaneous correlation between work and weight would be equal to the long-run effect, because staying an additional year in a particular job would have no further effect on weight. This is clearly not the case. Endogeneity of occupation seems even less likely when we consider the last column of Table 5, which depicts the results of a pooled regression with individual level fixed-effects. The coefficients on the job-related exercise variables reflect how a year-to-year change in average strenuousness affects an individual's weight. A one-year, one unit increase in average strenuousness lowers women's BMI by about 0.19 units, while a one-year increase in average strength requirements raises women's BMI by about 0.16 units. Since the 14-year

[14] Of course, some women do not report a 14-year occupation history, so the average effect is actually slightly smaller than this.

effects are only about six times as large as the one-year effects, it appears that job-related exercise has a concave effect on weight. This is consistent with the assumptions of our model.

Finally, consider one last alternative interpretation of our results for occupation: if changes in occupational strenuousness are driven entirely by changes in health status, then we are estimating the effect of changes in health status rather than the effect of changes in occupation. This interpretation, which would apply to our fixed-effects estimates as well, seems unlikely in this young population for several reasons.[15] First, switches into less strenuous jobs are *not* preceded by increases in BMI. People switching into less strenuous jobs between years t and $t+1$ actually gained 0.02 to 0.04 fewer units of BMI between $t-1$ and t, than the average NLSY respondent. This does not support the view that weight changes cause occupational changes. Second, changes in health are asymmetrically distributed. That is, people are much more likely to move from health into chronic illness, than to move in the other direction. This is not consistent with observed patterns of occupational change. Among workers who switch strenuousness levels from one year of the survey to the next, almost exactly half switch into more strenuous jobs. Indeed, using a t-test for equality of means, we are unable to reject the hypothesis that the probability of switching into a more strenuous job is one half. Third, people switching into less strenuous occupations have gained more education than the average worker. Switching females gain an average of 0.14 years of schooling; this is statistically distinguishable (using a t-test at the 5% level) from the average gain of 0.12 years of schooling. Switching males gain an average of 0.15 years of schooling, also statistically distinguishable from the overall average gain of 0.12 years. Finally, the average worker in the NLSY is likely to reduce her hours worked per week, from one year to the next, but those switching into less strenuous jobs reduce their hours worked by significantly less. This is true for both men and women, and passes a formal t-test at the 5% level.

So far, we have presented a thorough investigation of patterns for female workers. The analogous results for male workers are presented in Table 6. We continue to see the inverted U-shape effect of income, the positive effect of marriage, and the negative effect of education. Since the inverted U-shape effect of income for men survives the inclusion of fixed-effects, we can rule out the endogeneity of income as an explanation for our results.[16] Clearly, however, the

[15] We should also note that we pursued some instrumental variables strategies to estimate the effect of strenuousness. As instruments, we used (from March CPS data), the sex- and year-specific statewide relative wage in strenuous occupations, relative to sedentary occupations, and the statewide average levels of job strenuousness and strength requirements. These instruments turned out to be quite weak: first-stage IV regressions yielded t-statistics on the instruments below 2.0. The IV estimates had the same sign as the OLS estimates, although the magnitude of the coefficients was much larger (approximately ten times larger) and the standard errors were so much larger that the estimates were always insignificant.

[16] It has often been argued that increases in weight lower wages. Behrman and Rosenzweig (2001), however, present convincing evidence that the apparent causal link from weight to wages is generated entirely by unobserved individual factors, such as early childhood investments, which affect both. Since our effects survive the inclusion of individual fixed-effects, this type of individual heterogeneity can be ruled out as an explanation for our results.

most surprising result of Table 6 is the finding that occupation has no effect on weight. This is the only set of regressions that produces this result.

To understand this result, it is important to note that we do obtain significant effects when we analyze young men in the NLSY cohort using the NHIS data. The most relevant difference between the data sets, of course, is that the NHIS contains about ten times as many data points on this cohort as the NLSY. But why is sample size uniquely important for young men, rather than young women? It turns out that the relationship between strenuousness and age is unusually strong for young men. On average, young men who are one year older will have a strenuousness score of -.06 less; this is statistically significant, and the same relationship is estimated in both the NLSY and the NHIS data we analyzed earlier. In contrast, the relationship between age and strenuousness is essentially zero for women, and for men over the age of 40. Therefore, it is difficult to separate the effect of age and strenuousness for young men. Since age is measured nearly perfectly and strenuousness is measured with a fair amount of error, it is not surprising that including both in the same regression eliminates the effect of strenuousness, while leaving a significant effect of age. The NHIS has enough sample size to overcome this difficulty and separate the effects of age from strenuousness for young men, but the NLSY does not. This interpretation is also consistent with some experiments on subsamples of the NHIS. We took data from the NHIS on males of NLSY age, and randomly drew from these data samples of the size found in the NLSY. Using these smaller samples from the NHIS, we obtained *insignificant* effects of strenuousness nearly three-quarters of the time. Using the same NHIS data, but smaller samples, we found insignificant effects of occupation.

3.2.3 Unearned Income and Weight

The theory predicted different effects of income on weight depending on whether the income was earned in the labor market or elsewhere, such as in asset markets or from a spouse's earned income. We argued that a rise in income had two separate effects on weight $W(Y, S(Y))$. One was the direct effect of income on weight, and the second was the indirect effect the gain in income had on physical activity. We therefore predicted that the *slope* of the unearned income effect should be larger than the slope of the earned income effect if work was sedentary (non-sedentary), or if $S_Y > (<) 0$.[17] As more income is earned through a sedentary job, there is a rise in the price of exercising that partly or fully offsets the pure income effect. The analysis presented in this section allows us to separate the effects of earned income from the effects of unearned income.

The effects of unearned and earned income are analyzed in Table 7. The table shows regression results for married working females in the NLSY. The first column uses the standard set of dummies for the woman's own earnings decile (earned income). The second column uses a set of dummies for her husband's earnings decile (unearned income), while the third column uses

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[17] It is worth noting that changes in earned income, controlling for education and average occupational strenuousness, reflect at least two other forces: unobserved effort and unobserved human capital. The effect of earned income thus confounds the "pure" income effect with the effects of unobserved effort and ability. Therefore, one way of interpreting the large negative effects of earned income on the BMI of women is that women of higher unobserved ability choose to lower their weight.

both sets. Increases in the woman's earnings decile are likely to lower her BMI or leave it unaffected, but never to raise it. In contrast, women whose spouses earn in the bottom decile are substantially thinner than those above them. However, from the third decile upwards, increases in spousal earnings begin to reduce BMI. This is precisely the inverted U-shaped effect of unearned income that we hypothesized. Moreover, observe that earned income has the effect we observed in the NHIS analysis, namely that it decreases BMI nearly across the board. Therefore, it appears that the NHIS effect for women was driven largely by variation in earned income rather than unearned income. Earned income lowers the weight of women. This could be because women with higher labor force attachments have higher total labor supply, when one accounts for labor supplied at home and on the job. Alternatively, it could reflect a return to being thin. Some authors have argued that thinner women earn more on the labor market, although this view has recently come under attack.[18]

While the table provides clear evidence that unearned income has a non-monotonic relationship with weight, but it does not allow us to compare the slope of the two effects, because—to the extent that men and women have different wage distributions--the units of measurement differ for earned and unearned income. To compare the slopes of the two effects, we run the fully specified regression again, but use dummies for real income intervals, rather than income deciles. Specifically, for both earned and unearned income, we include a set of dummies for whether income fell between: 5,000-10,000; 10-20,000; 20-30,000; 30-40,000; 40-50,000; 50-60,000; 60-70,000; 70,000+. All values are in terms of constant 1983 dollars. Figure 4 graphs the resulting relationship between real income intervals and the BMI of married working women.[19]

FIGURE 4 INSERTED HERE

The x-axis represents the real income level, and the y-axis the change in weight induced by that level of income, relative to the group with zero to 5,000 dollars of income. Not only do we continue to see the inverted U-shaped relationship between real unearned income and weight, but we also see that the slope of the unearned income effect is much larger than that of the earned income effect, as soon as we cross the $10,000 threshold. Below this threshold, employment may not be sedentary.[20] Above this threshold, the observed pattern conforms to our prediction that the effect of earned income on weight is more positive than the effect of unearned income.

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[18] See Cawley (2000) for the view that weight lowers wages for women. Behrman and Rosenzweig (2001), however, use a unique sample of twins to argue that this correlation is spuriously generated by unobserved differences in early childhood investments.

[19] Restricting the analysis to *working* married women is not central to the results. We performed the analysis again for all married women, by dropping the job strenuousness variables, but keeping all other variables intact. We continued to find a significant, inverted U-shaped profile for unearned income and a declining profile for earned income.

[20] It is interesting to note that, even married women who earn in the $5,000-10,000 range tend to be full-time. Within this range, average hours worked per week is over 30, and four-fifths of women work more than 20 hours per week.

4 Conclusion

In this paper, we have developed the relationships among physical activity, income, food consumption, and weight, in the context of a rational-choice model. We have shown that reductions in physical activity lower food consumption but raise weight. Technological change that reduces physical activity may thus lower the demand for food at the same time that it raises weight. Income has different effects, depending on the level of income, and on its source. Growth in unearned income has a non-monotonic relationship with weight: it initially raises weight but eventually lowers it. Moreover, if physical strenuousness is negatively correlated with income, the effect of earned income on weight should be more positive than the effect of unearned income on weight.

We found support for all these predictions in our analysis of the NHIS and the NLSY. The empirical work illustrated a method for measuring the strenuousness of work, using publicly available data. These methods revealed negative effects of job-related exercise on weight. Moreover, changes across cohorts in the composition of work seem important in generating growth in weight over the long run. The analysis also revealed that unearned income has an inverted U-shaped relationship with weight, as predicted, and that the effect of unearned income tends to be lower than the effect of earned income.

The paper suggests several avenues of future research. First, an aspect of technological change we began to explore in the empirical work concerns changes in the price of food. It remains to show why the relative price of food seemed to decline so precipitously in the early 1980s. Technological change may have reduced the time and money costs of preparing food, with advances like the microwave and frozen food, for example. Alternatively, technological change in agriculture could have been responsible. More detailed analysis of the specific sources of technological change seems the logical next step in a research agenda that aims to understand the economics of weight gain.

Second, although the analysis here stresses the impact of technological change on the *quantity* of food and calorie consumption, it may have affected the *quality* of food intake as well. In particular, technological advances may have affected the relative prices of the different sources of calories such as e.g. proteins and fats. It is interesting to note that the food diary data from the NHANES suggests that the average diet contains a lower proportion of fat. The offsetting rise in the quantity of calories thus seems more important to understand.

Finally, although existing data constraints do not seem to allow for a systematic decomposition of weight growth into components due to food intake and physical activity, future data production should aim to make such decomposition feasible to better understand the different sources of technological change in raising weight.

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Table 1: Trends in weight and occupation, NHIS 1976-1994.

	Working Men		Working Women	
	1976	1994	1976	1994
BMI	24.93	26.19	23.12	24.65
Obesity	0.090	0.168	0.090	0.171
Age	38.568	38.469	37.109	38.625
Black	0.083	0.100	0.113	0.123
Married, Spouse Present	0.739	0.682	0.585	0.619
Highest Grade Attained	12.231	13.233	12.334	13.369
Distribution of Strength Requirements:*				
Strength=1	0.137 **	0.175	0.315 **	0.341
Strength=2	0.446 **	0.412	0.478 **	0.445
Strength=3	0.289 **	0.290	0.178 **	0.179
Strength=4	0.123 **	0.118	0.029 **	0.036
Strength=5	0.005 **	0.005	0.000 **	0.000
Distribution of Job-Related Exercise:†				
Strenuousness=0	0.300 **	0.271	0.255 **	0.308
Strenuousness=1	0.480 **	0.436	0.616 **	0.577
Strenuousness=2	0.226 **	0.242	0.090 **	0.078
Strenuousness=3	0.129 **	0.119	0.038 **	0.037

Source: NHIS, 1976-1994.

*From 1983 to 1994, Strength is rated on a continuous, non-integer scale, from 1 to 5. To derive these statistics, the interval from 1 to 5 is split into five equal intervals of 0.8 units each. For example, the Strength=1 category corresponds to a score between 1 and 1.8.

**Indicates 1983 value.

†From 1983 to 1994, Strenuousness is rated on a continuous, non-integer scale, from 0 to 3. To derive these statistics, the interval from 0 to 3 is split into four equal intervals of 0.75 units each. For example, the Strenuousness=0 category corresponds to a score between 0 and 0.75.

Table 2: Regression Results for NHIS, 1976-1994.

Dependent Variable:	Males			Females		
Adjusted BMI	Coefficient		T-Statistic[a]	Coefficient		T-Statistic[a]
S	-0.209	*	16.71	-0.102	*	5.17
Muscle	0.225	*	17.06	0.432	*	28.52
Income Quartile 1	-0.218	*	10.83	0.322	*	12.65
Income Quartile 2[b]	0		.	0		.
Income Quartile 3	0.025		1.52	-0.488	*	22.22
Income Quartile 4	-0.078	*	4.27	-0.908	*	37.61
Age	0.283	*	102.13	0.321	*	87.26
Age Squared	-0.003	*	89.91	-0.003	*	65.95
Highest Grade Completed	-0.107	*	43.19	-0.221	*	60
Year=1976	-1.036	*	29.21	-1.201	*	25
Year=1977	-0.92	*	17.35	-1.087	*	15.31
Year=1978	-0.875	*	24.2	-1.221	*	25.57
Year=1979	-0.913	*	25.16	-1.136	*	23.57
Year=1980	-0.841	*	22.69	-1.12	*	22.78
Year=1981	-1.338	*	33.93	-2.142	*	40.62
Year=1982	-0.743	*	20.24	-0.817	*	16.84
Year=1983	-0.702	*	19.06	-0.912	*	18.84
Year=1984	-0.948	*	22.13	-2.344	*	41.92
Year=1985	-0.528	*	13.62	-0.679	*	13.29
Year=1986	-0.423	*	9.75	-0.546	*	9.69
Year=1987	-0.374	*	10.1	-0.44	*	9.11
Year=1988	-0.306	*	8.31	-0.368	*	7.71
Year=1989	-0.153	*	4.03	-0.253	*	5.15
Year=1990	-0.106	*	2.79	-0.191	*	3.93
Year=1991[b]	0		.	0		.
Year=1992	0.162	*	4.04	0.177	*	3.47
Year=1993	0.219	*	5.19	0.197	*	3.69
Year=1994	0.306	*	7.63	0.3	*	5.7
Northeast	-0.008		0.44	0.017		0.73
North-Central	0.109	*	6.51	0.293	*	13.03
South						
West	-0.358	*	20.65	-0.179	*	7.78
Black	0.109	*	4.44	1.997	*	66.78
Married, Spouse Present	0.655	*	41.05	-0.055	*	2.82
Constant	20.306	*	277.97	19.404	*	207.26
Observations	439628			361332		
R-Squared	0.08			0.12		

*Significant at 99% Level.

**Significant at 95% Level.

[a]Based on robust standard errors.

[b]Indicates omitted category.

Table 3: Correlation between changes of relative food prices and BMI.

Error Structure	Males		Females	
I.I.D.	-4.65	*	-5.48	*
	(5.82)		4.25	
Heteroskedastic	-4.65	*	-5.53	*
	(5.86)		4.31	
Cross-Correlation	-2.11	**	-3.70	*
	(2.21)		2.65	
Heteroskedastic,	-1.94	**	-4.92	*
AR(1)	(1.97)		2.66	
Cross-Correlation	-0.70		-3.19	***
AR(1)	(0.64)		1.71	
Heteroskedastic,	-1.88	*	-6.49	*
Unstructured AR	(5.16)		24.21	

*Significant at 1% level.
**Significant at 5% level.
***Significant at 10% level.

Table 4: Summary Statistics for NLSY, 1982-1998.

	Working Men		Working Women	
	1982	1998	1982	1998
BMI	23.5	26.9	22.1	26.2
Obesity	0.05	0.22	0.05	0.27
Age	20.7	37.0	20.7	37.0
Black	0.14	0.14	0.14	0.14
Hispanic	0.06	0.07	0.06	0.06
Married	0.17	0.63	0.30	0.66
Highest Grade Attained	12.0	13.4	12.2	13.4
Distribution of Strength Requirements:				
Strength=1	0.307	0.256	0.419	0.357
Strength=2	0.589	0.672	0.479	0.574
Strength=3	0.058	0.041	0.087	0.051
Strength=4	0.044	0.029	0.015	0.017
Strength=5	0.003	0.002	0.000	0.001
Distribution of Job-Related Exercise:				
Strenuousness=0	0.435	0.373	0.436	0.398
Strenuousness=1	0.482	0.570	0.545	0.593
Strenuousness=2	0.019	0.030	0.004	0.004
Strenuousness=3	0.064	0.027	0.015	0.006

Source: NLSY, 1982-1998.

Table 5: Dynamic effects of occupation among young working women in the NLSY.

	Pooled[a]		1996[b]		Fixed-Effects[c]	
S	-0.35	*				
	3.64					
Muscle	0.33	*				
	4.23					
S Stock			-1.22	*	-0.19	*
			2.49		1.99	
Muscle Stock			0.94	*	0.16	*
			2.51		2.06	
Highest Grade Completed	-0.16	*	-0.12	*	-0.03	
	5.02		2.01		1.11	
Black	2.63	*	3.73	*		
	13.71		11.32			
Hispanic	1.10	*	1.48	*		
	5.24		4.01			
Married	-0.09		-0.18		0.59	*
	0.73		0.64		12.95	
Wage Decile 1[d]	0.00		0.00		0.00	
	.		.		.	
Wage Decile 2	-0.12		-0.33		-0.20	*
	0.47		0.65		1.99	
Wage Decile 3	-0.11		-0.02		-0.21	*
	0.65		0.03		2.81	
Wage Decile 4	0.07		-0.13		-0.29	*
	0.37		0.24		3.96	
Wage Decile 5	-0.26		-0.34		-0.26	*
	1.45		0.63		3.36	
Wage Decile 6	-0.19		-0.23		-0.36	*
	1.03		0.42		4.61	
Wage Decile 7	-0.35	**	-0.59		-0.43	*
	1.83		1.08		5.33	
Wage Decile 8	-0.49	*	-0.77		-0.44	*
	2.43		1.28		5.21	
Wage Decile 9	-0.86	*	-1.64	*	-0.50	*
	4.18		2.65		5.51	
Wage Decile 10	-1.05	*	-1.56	*	-0.52	*
	4.39		2.40		4.72	
Constant	16.61	*	-29.81		23.09	*
	12.93		0.93		70.18	
Year Effects	Yes		No		Yes	
Quadratic in Age	Yes		Yes		No	
Observations	33655		2358		31344	
R-squared	0.12		0.09		0.22	

Robust t-statistics in parentheses
*Significant at the 95% level.
**Significant at the 90% level.
[a]Standard errors are clustered by individual.
[b]Includes only 1996 observations.
[c]Includes person-level fixed-effects.
[d]Indicates excluded group.

Table 6: Dynamic effects of occupation among young working men in the NLSY.

	Pooled[a]			1996[b]			Fixed-Effects[c]	
S	-0.02							
	0.25							
Muscle	0.10							
	1.63							
S Stock				-0.01			0.06	
				0.02			1	
Muscle Stock				0.42			0.014	
				1.22			0.23	
Highest Grade Completed	-0.09	*		-0.09	*		-0.056	*
	3.77			1.96			3.09	
Black	0.07			0.80	*			
	0.49			3.21				
Hispanic	0.76	*		1.07	*			
	4.05			3.54				
Married	0.45	*		0.65	*		0.398	*
	4.14			2.91			11.52	
Wage Decile 1[d]								
Wage Decile 2	0.17			1.83	*		0.087	
	0.76			2.77			0.89	
Wage Decile 3	-0.05			1.24	**		0.119	**
	0.31			1.92			1.65	
Wage Decile 4	0.17			1.53	*		0.146	*
	1.04			2.56			2.17	
Wage Decile 5	0.25			1.54	*		0.102	
	1.54			2.51			1.54	
Wage Decile 6	0.33	*		1.57	*		0.084	
	1.99			2.63			1.27	
Wage Decile 7	0.48	*		1.96	*		0.163	*
	2.80			3.36			2.44	
Wage Decile 8	0.64	*		1.95	*		0.126	**
	3.85			3.23			1.87	
Wage Decile 9	0.35	*		1.36	*		0.062	
	2.15			2.42			0.92	
Wage Decile 10	0.42	*		0.97	**		-0.003	
	2.49			1.69			0.05	
Constant	15.56	*		-21.50			23.777	*
	15.62			0.91			98.12	
Year Effects	Yes			No			Yes	
Quadratic in Age	Yes			Yes			No	
Observations	35427			2458			32928	
R-squared	0.09			0.03			0.27	

Robust t-statistics in parentheses

*Significant at the 95% level.

**Significant at the 90% level.

[a]Standard errors are clustered by individual.

[b]Includes only 1996 observations.

[c]Includes person-level fixed-effects.

[d]Indicates excluded group.

Table 7: Unearned and Earned Income Effects for Married Female Workers in the NLSY, 1982-1996.

Dependent Variable:	Married Females								
Adjusted BMI	Coefficient		T-Statistic[a]	Coefficient		T-Statistic[a]	Coefficient		T-Statistic[a]
S	-0.425	*	-3.21	-0.487	*	3.71	-0.442	*	3.33
Muscle	0.279	*	2.59	0.275	*	2.55	0.279	*	2.56
Wage Decile 1[b]	0		.	0		.	0		.
Wage Decile 2	-0.211		0.61				-0.132		0.34
Wage Decile 3	-0.173		0.85				-0.379	**	1.81
Wage Decile 4	0.081		0.36				-0.147		0.62
Wage Decile 5	-0.333		1.39				-0.57	*	2.29
Wage Decile 6	-0.279		1.1				-0.552	*	2.13
Wage Decile 7	-0.63	*	2.48				-0.784	*	2.98
Wage Decile 8	-0.555	*	2.05				-0.635	*	2.29
Wage Decile 9	-1.09	*	4.11				-1.151	*	4.23
Wage Decile 10	-1.237	*	3.94				-1.219	*	3.82
Spouse Wage Decile 1[b]	0		.	0		.	0		.
Spouse Wage Decile 2				1.97	*	2.51	2.137	*	2.46
Spouse Wage Decile 3				1.564	*	3.81	1.509	*	3.62
Spouse Wage Decile 4				2.102	*	6.21	2.07	*	6.06
Spouse Wage Decile 5				1.442	*	5.44	1.472	*	5.52
Spouse Wage Decile 6				0.848	*	3.56	0.931	*	3.84
Spouse Wage Decile 7				0.594	*	2.7	0.681	*	3.09
Spouse Wage Decile 8				0.245		1.11	0.347		1.56
Spouse Wage Decile 9				-0.019		0.09	0.072		0.33
Spouse Wage Decile 10				-0.69	*	3.14	-0.563	*	2.56
Age	0.341	*	2.07	0.35	*	2.1	0.409	*	2.37
Age Squared	-0.004		1.17	-0.003		1.07	-0.004		1.33
Highest Grade Completed	-0.168	*	4.17	-0.159	*	4.1	-0.11	*	2.68
Year=1982									
Year=1985	0.191		1.13	0.092		0.54	-0.019		0.11
Year=1986	0.72	*	3.45	0.542	*	2.62	0.481	*	2.23
Year=1988	0.804	*	2.92	0.658	*	2.35	0.456		1.61
Year=1989	0.946	*	3.07	0.81	*	2.63	0.616	*	1.98
Year=1990	1.177	*	3.42	0.941	*	2.69	0.784	*	2.23
Year=1992	1.613	*	3.9	1.352	*	3.23	1.154	*	2.74
Year=1993	1.652	*	3.62	1.35	*	2.95	1.177	*	2.54
Year=1994	1.758	*	3.33	1.103	*	2.09	0.798		1.46
Year=1996	2.241	*	3.74	1.687	*	2.8	1.453	*	2.34
Black	2.731	*	9.87	2.576	*	9.01	2.578	*	8.94
Hispanic	1.258	*	4.58	1.052	*	3.95	1.109	*	4.11
Constant	18.716	*	8.61	17.62	*	7.89	16.708	*	7.27
Observations	15930			15346			15035		
R-Squared	0.1			0.11			0.11		

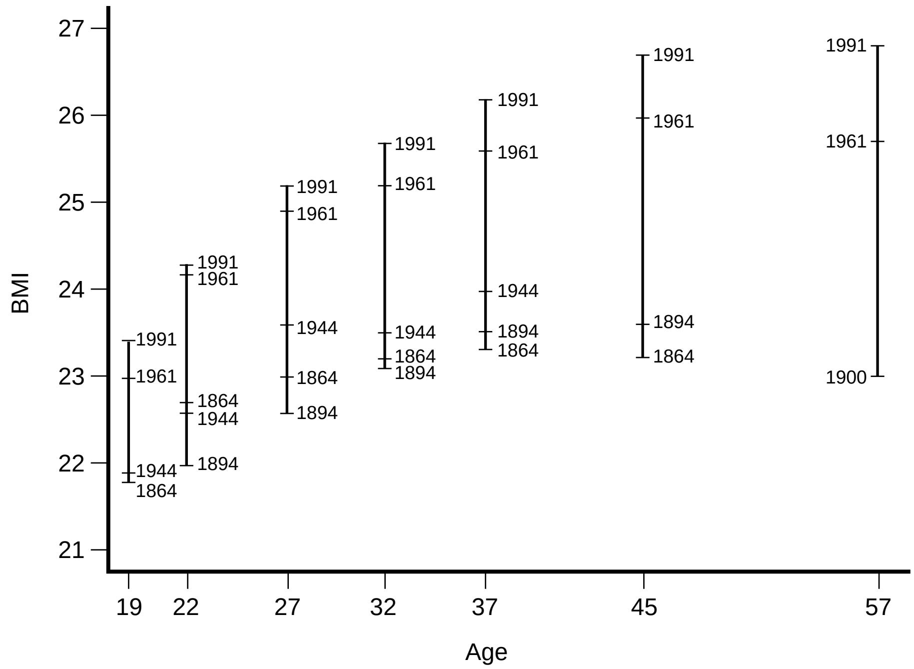
*Significant at the 95% level.

**Significant at the 90% level.

[a]Based on robust standard errors.

[b]Indicates omitted category.

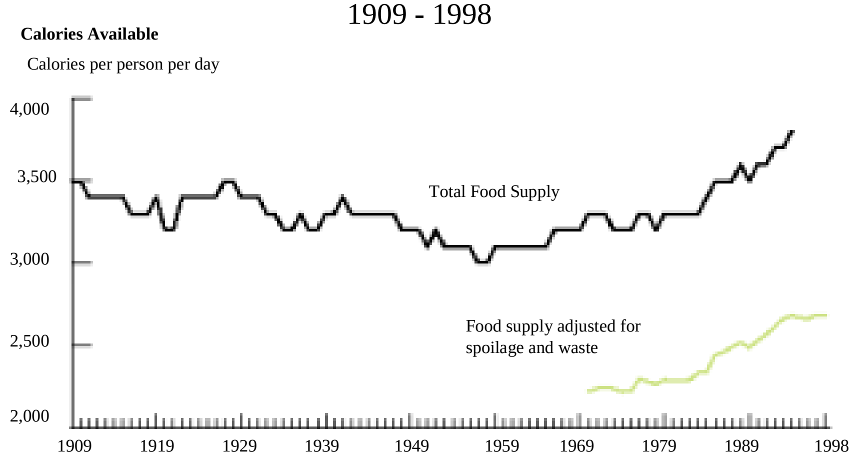
Figure 1: Historical Change in US Body Mass Index: 1863-1991.



SOURCE: Costa D. and R. Steckel (1995), NBER Historical WP #76.

Figure 2: Long-Run Changes in Calorie Consumption.

Calories Available From the Food Supply per Person per Day, 1909 - 1998



Source: USDA's Economic Research Service

Figure 3: Reporting Bias in Weight Data, by Sex and Race.

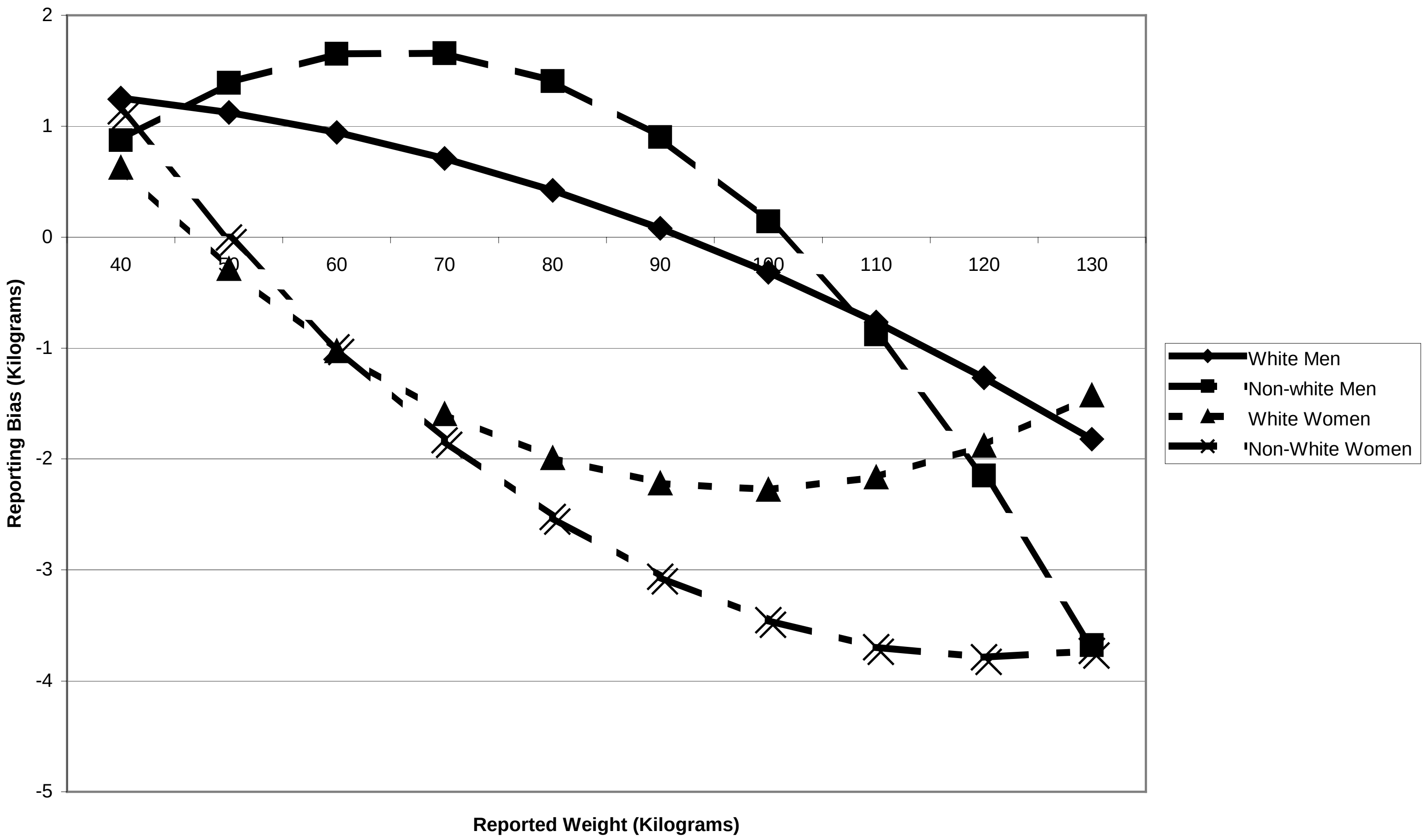


Figure 4: Effect of Earned and Unearned (Spouse's) Income on the BMI of Married Women.

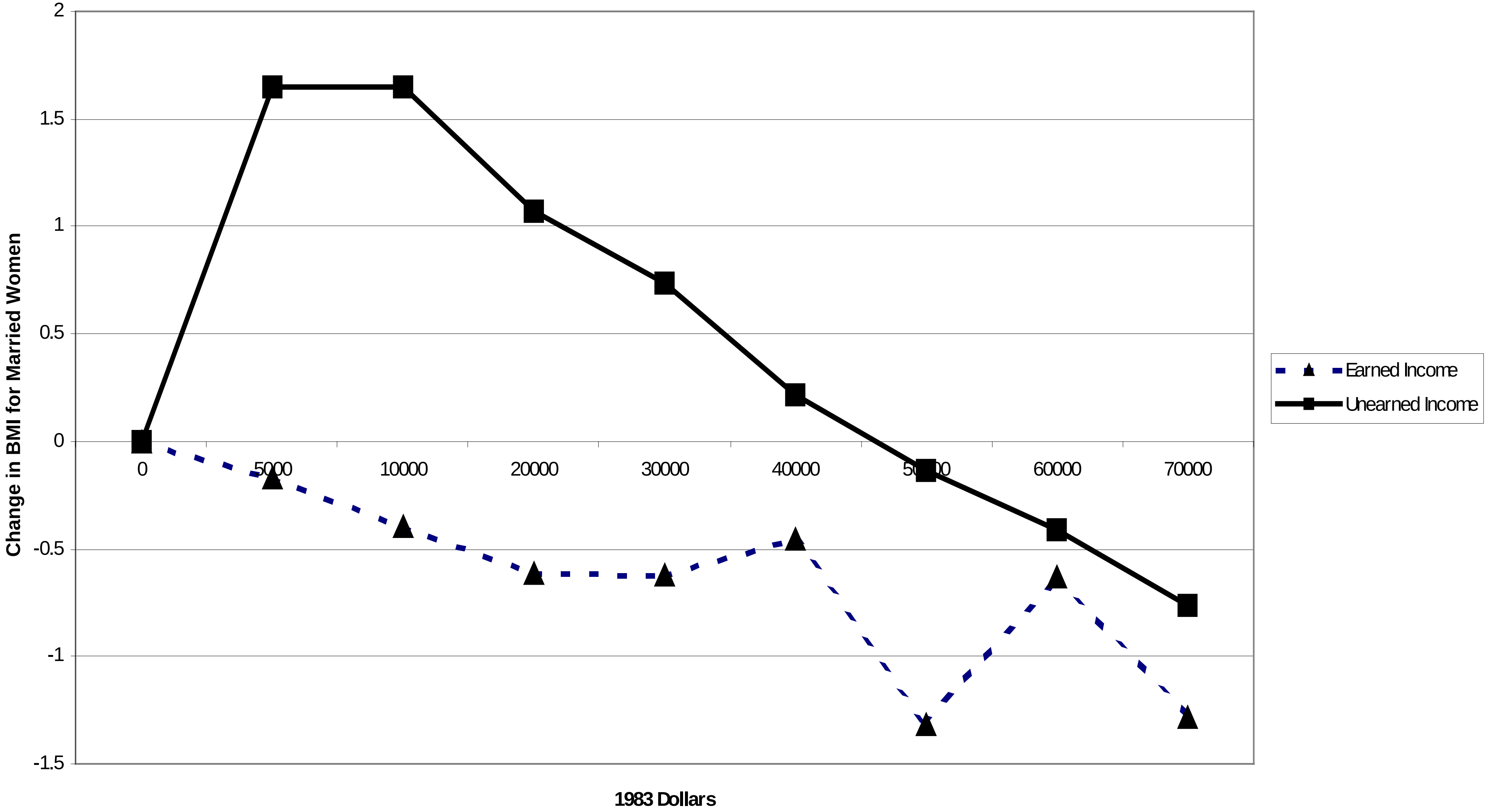


Figure 5: Change in the relative price of food, for US regions, 1976-1994.